

Optimizing both print time and quality of 3D printed objects

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Introduction

This project focused on the fabrication of three dimensional objects using additive manufacturing techniques. The technique used was a Fused Deposition Modeling (FDM) 3D printer which creates objects by slicing them into horizontal layers and creating each layer out of a melted filament. 3D printers can use various types of filament, ranging from inexpensive ABS or PLA plastics, to high-end engineering plastics such as polycarbonate or carbon-fiber impregnated filament. FDM printers heat the filament and then extrude it onto a platform to create layers (Stratasys, 2017). Due to the way that 3D printers print objects, curves in the z plane will naturally be extruded as stair steps when layer height is too high (low-resolution). However, having a very low layer height (high-resolution) can lead to high print times. In 2015, 3D Matter did tests on layer height and infill density's effects on print time and quality. Their data, in Charts 1 and 2, led them to conclude that layer height is inversely proportional to print time and quality.

Quality	Infill %						
	10	30	50	70	80	90	100
Layer Height (mm)	0.1	Very High					Low
	0.15	High					
	0.2	Medium					
	0.25	Low					
	0.3	Very Low					

Chart 1: How layer height and infill percentage affect surface quality of an object. (3D Matter, 2015)

Time (mins)	Infill %							
	10	30	50	70	80	90	100	
Layer Height (mm)	0.1	21	31	47	61	68	74	80
	0.15	14	23	32	41	46	50	54
	0.2	10	18	24	31	35	38	41
	0.25	8	14	20	25	28	31	33
	0.3	7	12	16	21	24	26	28

Chart 2: How layer height and infill percentage affect print time of an object (3D Matter, 2015)

This project aims to lower print times, without reducing quality, by raising the layer height of the inside of the print; allowing a user to print the interior of their object with a low resolution while still printing the outside of their object with a high resolution. This was done by splicing together 4 user created g-codes, with 2 differing resolutions. G-code is produced by a slicer tool and is a representation of the object as vector movement and extrusion commands. The infill code from the low-resolution g-code was coated by the exterior code from the high-resolution g-code. This would theoretically reduce the print time of the object when compared to its high-resolution version.

Materials and Methods

This project used an Ultimaker 2 printer which runs a custom 'flavor' of gcode called Ulti-g-code. The first step in processing is generating four g-code files with the same slicing tool. The first two files must have different layer heights. The larger layer height must

Materials and Methods (cont.)

also be an integer multiple of the smaller height. The second two files must both have 0% infill but otherwise have the same settings as the first two files. The application then cross references the hollow and full files to find the infill portion. This portion is copied into an output file along with the exterior moves of the hollow high resolution file. The final output file was verified by printing on the Ultimaker 2 using PLA plastic filament. Tested objects are shown in Figure 1.



Figure 1. Printed test objects from left to right: Rectangle, Pyramid, Torus, Filleted Cube, Curved Corner

Print times were measured using an Arduino® microcontroller that started counts based on a limit switch under the print bed on the Ultimaker 2. This limit switch is released when the bed rises at the start of the print and is compressed when the bed returns to the base of the printer after finishing the print. By counting the time between switch activations, a very accurate measure of print time can be found. The print time displayed on the Ultimaker's display is only an estimate, and is often inaccurate. The external Arduino® clock provided a more reliable measure of how long the prints took.

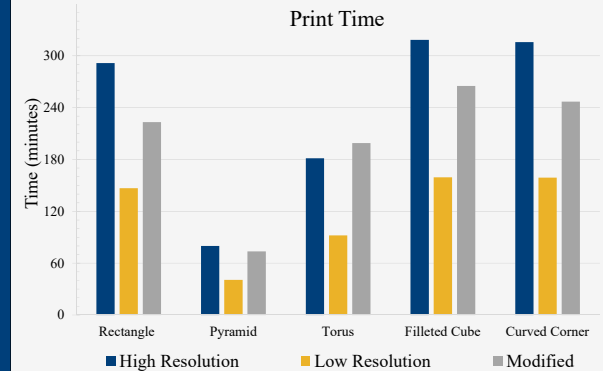
Results

Compared to the high resolution version of the object, the modified object typically printed in 10%–20% less time. This time savings was improved dramatically in objects with a higher infill percentage. A rectangle with 100% infill experienced a 24% time savings.

The application did not decrease the print time of complex objects and objects with internal holes. Due to the complex order of actions needed during printing, the application had to add multiple extra moves to ensure the outer surface of the object printed correctly. This led to the modified file taking 10%–30% more time to print.

Graph 1 shows that the high resolution version of each object had a print time of about 1.9 times the print time of the low resolution object. The object, after being modified by the application, prints in about 1.5–1.6 times that of the low resolution object. Objects with an internal hole, such as doughnut shapes, did not follow this trend.

Results (cont.)



Graph 1. Print time (in seconds) of the different test files. High resolution has half the layer height of low resolution. Modified is the object created by the application.

Conclusions

The data supports the theory that objects with higher layer heights print faster. By increasing the layer height of objects' infill it was possible to make them print faster. The amount of time saved was related to how similar the object was to a cube. By raising interior layer height, the inside of the object was forced to approach a more cubical shape. Objects that were more similar to cubes would allow for more of the infill to be modified, increasing the time savings. Due to a limited data set these results can't be extrapolated to other printers and materials without further testing. The theory should hold for other materials, printers, and g-code flavors although this application's algorithm may not. Further research is needed to generalize the algorithm to apply to all objects and g-code flavors.

References

- 3D Matter. (2015). *What is the influence of infill %, layer height and infill pattern on my 3D prints*. Retrieved From <http://my3dmatter.com/infill-layer-height-pattern/>
- Stratasys. (2017). *FDM technology*. Retrieved From <http://www.stratasys.com/3d-printers/technologies/fdm-technology>

Acknowledgements

Thank you Mr. Davis and Mr. Contrevo for help completing this project.